Journal of Taibah University Medical Sciences (2019) 14(4), 337–342

Taibah University

Journal of Taibah University Medical Sciences

www.sciencedirect.com

Original Article

Effect of cardiac surgery on respiratory muscle strength

Bangi A. Naseer, MPTh [a], Abdullah M. Al-Shenqiti, PhD [a], Abdul Rahman H. Ali, PhD [a,*] and Talal Aljeraisi, MS [b]

[a] *Faculty of Medical Rehabilitation Sciences, Taibah University, KSA*
[b] *Head & Neck Surgery Department, Faculty of Medicine, Taibah University, KSA*

Received 26 February 2019; revised 1 June 2019; accepted 3 June 2019; Available online 9 July 2019

Abstract

Objectives: Pulmonary complications, such as atelectasis, pulmonary oedema, pleural effusion, bronchospasm, and pneumonia, have been reported following cardiac surgery. Shallow breathing leading to impaired lung function is the major cause of respiratory complications. Decreases in respiratory muscle strength can be measured using the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) produced in the oral cavity. This study aimed to determine the decrease in respiratory muscle strength 8 weeks following cardiac surgery. Moreover, the relationship between lung function and respiratory muscle strength was studied.

Methods: In this observational study, 42 adult cardiac surgery patients (10 women, 32 men; mean age 65 ± 7 years) were investigated. Lung function and respiratory muscle strength were measured preoperatively and at 2 months postoperatively.

Results: The pre- and postoperative respiratory muscle strengths were in accordance with the predicted values. The MIP was 81.75 ± 22.04 cmH_2O preoperatively and 74.56 ± 18.86 cmH_2O at the 2-month follow-up ($p = 0.146$). The MEP was 98.55 ± 22.24 cmH_2O preoperatively and 88.86 ± 18.14 cmH_2O at the 2-month follow-up ($p = 0.19$). The preoperative lung function was in accordance with the predicted values; however, lung function significantly decreased postoperatively. At the 2-month follow-up, there was a moderate correlation between the MIP and forced expiratory volume ($r = 0.59$, $p = 0$ .0078).

Conclusions: The respiratory muscle strength was not impeded either before or 2 months after cardiac surgery. However, the exact mechanism for the alteration in lung function remains unclear. Measures to re-establish the ideal postoperative lung capacity should concentrate on different perioperative pulmonary exercises.

الملخص

أهداف البحث: سبق وأن تم الإبلاغ عن مضاعفات رئوية مثل الانخماص، والوذمة الرئوية، والانصباب الجنبي، والتشنج القصبي والالتهاب الرئوي خلال الفترة التي تتلو عمليات جراحة القلب. يُعتبر التنفس الضحل المؤدي إلى ضعف وظائف الرئة السبب الرئيس لمضاعفات الجهاز التنفسي. ويمكن قياس انخفاض قوة العضلات التنفسية عن طريق الضغط الشهيقي الأقصى والضغط الزفيري الأقصى الناتج في تجويف الفم. هدفت هذه الدراسة إلى تحديد انخفاض قوة العضلات التنفسية بعد ثمانية أسابيع من جراحة القلب. علاوة على ذلك، تمت دراسة العلاقة بين وظيفة الرئة وقوة العضلات التنفسية.

طرق البحث: في هذه الدراسة المبنية على الملاحظة، تمت دراسة ٤٢ مريضا من مرضى جراحة القلب البالغين (أعمارهم ٦٥ ± ٧ سنوات). كان هناك ١٠ نساء و٣٢ رجلا. تم قياس وظيفة الرئة وقوة العضلات التنفسية قبل العملية وشهرين بعد العملية.

النتائج: كانت قوة عضلات الجهاز التنفسي قبل وبعد العملية الجراحية وفقا للقيم المتوقعة؛ حيث كان الضغط الشهيقي الأقصى قبل العملية ٨١.٧٥+/- ٢٢.٠٤سم ماء، وبعد العملية بشهرين ٧٤.٥٦+/- ١٨.٨٦سم ماء. وكان الضغط الزفيري الأقصى قبل العملية ٩٨.٥٥+/- ٢٢.٢٤ سم ماء، وبعد العملية بشهرين ٨٨.٨٦+/- ١٨.١٤سم ماء. وكانت وظيفة الرئة قبل العملية وفقا للقيم المتوقعة، إلا أنه انخفضت بشكل ملحوظ بعد العملية. في زيارة المتابعة بعد العملية بشهرين، وكانت هناك علاقة معتدلة بين الضغط الشهيقي الأقصى وحجم الزفير القسري.

الاستنتاجات: أظهرت هذه الدراسة أن قوة عضلات الجهاز التنفسي لم تعرقل، لا سابقا ولا شهرين بعد جراحة القلب. ولكن الآلية المحددة لهذا التعديل في وظائف الرئة ليست مفهومة بشكل واضح. يجب أن تركز التدابير الرامية إلى إعادة تحديد القدرة المثالية للرئة بعد العملية الجراحية على تمارين رئوية مختلفة قبل وبعد العملية.

الكلمات المفتاحية: جراحة القلب؛ وظيفة الرئة؛ قوة العضلات التنفسية؛ الضغط الشهيقي الأقصى؛ الضغط الزفيري الأقصى

* Corresponding address: College of Medical Rehabilitations, P.O. Box 388, Taibah University, Almadinah Almunawwarah, KSA.

E-mail: abrrahman@hotmail.com (A.R.H. Ali)

Peer review under responsibility of Taibah University.

ELSEVIER Production and hosting by Elsevier

1658-3612 https://doi.org/10.1016/j.jtumed.2019.06.002

Keywords: Cardiac surgery; Lung function; Maximal expiratory pressure (MEP); Maximal inspiratory pressure (MIP); Respiratory muscle strength

Introduction

The complications of lung function impairment can be caused by various factors, one of which is pain. Owing to the presence of pain, shallow breathing may occur in patients, which will restrict their chest movement following cardiac surgery with median sternotomy.[1–7] The muscles for breathing, i.e. mainly the diaphragm, are important for inspiration. Surgeries in the chest might involve the muscles and nerves. Dysfunction of the respiratory muscles preoperatively might prolong mechanical ventilation after cardiac surgery, such as coronary artery bypass grafting (CABG), mitral valve replacement, and aortic valve replacement, and reduce respiratory muscle strength, which has been known to be a determinant of reduced functional capacity postoperatively.[8,9] Decreases in respiratory muscle strength can be measured using the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) produced in the oral cavity; this has been reported in hospitalised patients after cardiac surgery.[10–13] Conversely, the reported recovery time after discharge ranged from 6 to 8 weeks in some studies but was unknown in other studies. Respiratory muscle exercises have been provided for the treatment of patients before and after cardiac surgery for improving their respiratory muscle strength and preventing complications. Studies have shown favourable useful effects of respiratory muscle training before and after surgery to re-establish and improve inspiratory muscle strength,[10,11] increase forced vital capacity (VC),[14] and reduce the incidence of pneumonia and hospitalisation.[15] Conversely, other studies have not found any effect.[16] After surgery, lung function improves progressively; however, a postoperative decrease of lung function from 6% to 13% has been reported as compared with that in the preoperative period.[17] Numerous factors that affect postoperative lung function have been reported, e.g. postoperative inflammatory reaction, pleural variations, and atelectasis.[18] The reduction of lung function postoperatively has been emphasised with incisional pain; nevertheless, this resolves months after surgery.[17] The relationship between respiratory muscle strength and lung function after cardiac surgery is not known.

The purpose of this study was to evaluate the respiratory muscle strength before and 8 weeks after cardiac surgery and determine its relationship with lung function.

We hypothesised that the respiratory muscle strength will substantially decrease 8 weeks after cardiac surgery and is related to lung function.

Materials and Methods

This study was a prospective observational study and reviewed data from 42 patients who were included in a randomised control trial designed to investigate the effect of breathing exercises in post-cardiac surgery patients.[19] Ethical committee approval was obtained. The study protocol and procedures were explained to all subjects. Complete written informed consent was also obtained from all subjects before collecting their baseline measurement data. The study was conducted at the Delhi Heart and Lung Institute from 2014 to 2015.

Inclusion criteria

The inclusion criteria were as follows: age of >35 years, ability to communicate in local language or English language, upcoming valve surgery or coronary artery bypass surgery (cardiac surgery) via median sternotomy, ejection fraction of >35%, and presence of an internal mammary artery graft, a saphenous vein graft, or a radial graft.

Exclusion criteria

The exclusion criteria were as follows: emergency cardiac surgery, history of pulmonary or cardiac surgery, kidney disease, absence of the need for mechanical ventilation for >24 h or reintubation, and absence of infection or unstable sternum.

Procedures and settings

Physiotherapists recruited patients from the department of cardiothoracic and vascular surgery at the Delhi Heart and Lung Institute and obtained their preoperative data. Respiratory muscle strength, oxygen saturation, and spirometry results were assessed by pulmonary laboratory technologists from the department of pulmonology critical care and sleep medicine before and 8 weeks after surgery. The patients' medical records on physical condition were collected. The patients underwent surgery under general anaesthesia, and ventilation was preserved above 90% with supplemental oxygen. For the first four postoperative days, deep breathing exercises were performed hourly by all subjects. A positive end expiratory pressure device and an incentive spirometer were used for the breathing exercises. The exercise regime comprised three sets of 10 repetitions of deep breathing exercises, with a breath hold of 5–10 s and breathing out in the device.[19] During the first postoperative day, the breathing exercises were performed hourly. Progressive mobilisation was provided by the nursing staff and physiotherapists on the second postoperative day by making the patients sit on the side of their bed, followed by standing and short walking inside the room. On the third postoperative day, the patients were instructed to walk a longer distance in the passageway of the hospital. On the fourth postoperative day, the exercises were repeated.[19]

Throughout hospitalisation, pain relievers (analgesics) were administered in all patients as per the regular routine in the hospital.

Outcomes and measurements

The respiratory muscle strength was assessed using the MEP and MIP produced in the mouth. During assessment, the patients were sitting and had to breathe through a mouth piece, while their nose was closed with a nasal clip. The MEP was measured near the total lung capacity after maximum inhalation and the MIP near the residual volume after maximum exhalation. The best values out of the three standard manoeuvres were noted. As per the American Thoracic Society/European Respiratory Society (ATS/ERS) 'Statement on Respiratory Muscle Testing', the inspiratory and expiratory muscle tests were standardised. The respiratory muscle strength was measured using the MIP and MEP generated at the mouth. The patients were in a seated position, breathing in a flanged mouthpiece and wearing a nose clip. The MIP was measured near the residual volume after maximal exhalation and the MEP near the total lung capacity after maximal inhalation. The highest values from three technically acceptable manoeuvres were recorded. The inspiratory and expiratory muscle tests were standardised, as described in the ATS/ERS 'Statement on Respiratory Muscle Testing'.[20] Further, the Jaeger respiratory drive MS-PFT/ muscle strength (Care Fusion Germany) was used. For assessing the MEP and MIP, non-invasive measurements were extensively applied and acknowledged.[11,21,22] The test-retest reliability for patients with chronic obstructive pulmonary disease showed an r value of 0.97,[24] while that for healthy individuals showed an ICC of > 0.8.[23] For cardiac surgery patients, no reliability or validity tests have yet been established. According to Evans and Whitelaw, the MEP and MIP were related to age and sex for predicted values.[25] The inspiratory capacity (IC), VC, and forced expiratory volume in 1 s (FEV_1) were evaluated using the Jaeger Screen PFT/body box (Care Fusion Germany). In the sitting position, spirometry was performed and standardised as described in the ATS/ERS 'Standardisation of Spirometry'.[26,27] The expected values for the IC, VC, and FEV_1 were correlated to sex, age, and height, as reported by Hedenstrom et al.[28,29] Pulse oximetry was used for the measurement of oxygen saturation (Beurer GmbH, Germany), with a finger probe attached to the patients' finger.

Statistical analysis

Data were gathered from different healing centres in the western region of the KSA and made accessible by sex, age, indications, types, surgical type, hazard factors, nationality, and pre- and postoperative treatment type. The technique for information accumulation has been utilised for this examination reason for existing was affirmed by the medicinal moral panel and authority letter from the individual division. Data were gathered dependent of the manifestations and treatment provided with their age, sex, nationality, and healing centre subtleties.

Data were analyzed using the SPSS statistical software version 20, and the outcomes are shown in Table 2 and in Graph 1. Normality distribution was assessed using the Kolmogorov−Smirnov test. The Pearson correlation of various variables, such as the preoperative and postoperative values of the MEP, MIP, oxygen saturation, and lung function, was assessed using Student's paired t-test and chi-square test. The results were presented as means ± standard deviations (SDs), with p value estimation (<0.05).

Results

A total of 42 patients undergoing CABG (n = 28) and valve surgery (n = 14) via average sternotomy with a mean age of 65 ± 7 years were surveyed (Table 1). There were no significant differences in the patient characteristics between the CABG patients and valve surgery patients.

The patient characteristics, e.g. age, body mass index (BMI), weight, and surgical status, are shown in Table 1. There was a significant decrease in weight and BMI 2 months after cardiac surgery. These findings were anticipated. Eight patients were current smokers, and 12 and 13 had airflow obstruction and diabetes before surgery, respectively.

Regarding lung volumes, the VC, FVC, and FEV_1 significantly increased. The ERV increased, and the IRV decreased, keeping the VT unaltered 1 year after surgery. Further, respiratory perseverance evaluated using the MVV also increased after weight reduction (Table 2).

In the evaluation of the respiratory muscle quality, a decrease critical in the estimations of the MIP and MEP was recorded (Table 3).

Table 1: Patient characteristics - pre- and postoperative means ± SDs, n = 42.

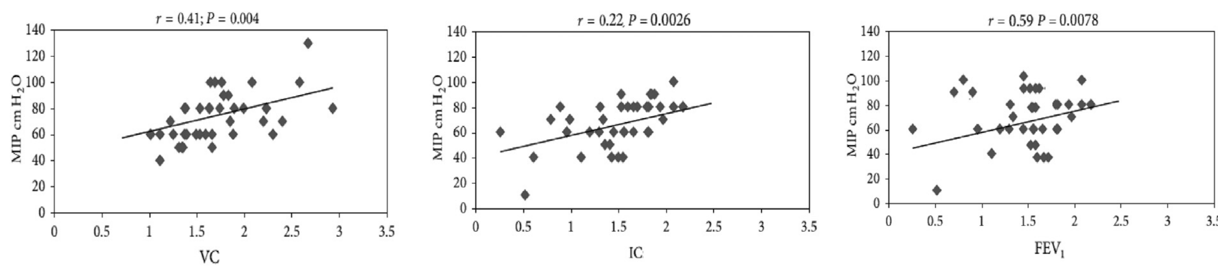
Variable	Preoperative
Mean age (year) ± SD	65 ± 7
Age (year)	>35
Female sex, n (%)	10 (24%)
Male sex, n (%)	32 (76%)
BMI, kg/m2	29 ± 4
New York Heart Association classification	
I-III A, n (%)	24 (57%)
IIIB-IV, n (%)	12 (48%)
Airflow obstruction, n (%)	12 (48%)
Diabetes, n (%)	13 (31%)
Smoking	
Current smoker, n (%)	8 (19.5%)
Stopped, n (%)	12 (48.5%)
Never smoked, n (%)	22 (52%)
Surgery (preoperative)	
CABG, n (%)	28 (67%)
Valve surgery, n (%)	14 (33%)
CABG + valve surgery, n (%)	0 (0%)
ECC time (minute)	102 ± 39
Postoperative	
Operative time	4.7 ± 1.8
Postoperative hospital stay[a]	
1 week (5−7 days)	27
2 weeks (10−14 days)	9
3 weeks (>14 days)	5

BMI, body mass index.
CABG, coronary artery bypass grafting.
ECC, extracorporeal circulation.
SD, standard deviation.
[a]1 missing value.

Table 2: Values of lung function; means ± SDs, n = 42.

Variable	Preoperative	Postoperative (2 months)	*p* value
VC	4.1 ± 0.62	3.8 ± 0.85	0.0046
VC (%)	95.69% ± 12.85%	92.29% ± 12.45%	
IC	2.35 ± 0.42	3.1 ± 0.56	<0.001
IC (%)	98.88% ± 10.72%	92.05% ± 12.25%	
FEV_1	2.87 ± 0.45	2.5 ± 0.68	0.0001
FEV_1 (%)	98.11% ± 10.21%	88.15% ± 10.75%	

VC, virtual capacity.
FEV_1, forced expiratory volume in 1 s.
IC, inspiratory capacity.
SD, standard deviation.



Graph 1: Correlation of the MIP in cmH_2O with the VC, IC, and FEV_1, The data shown indicate the preoperative and postoperative values of 42 patients. MIP, maximal inspiratory pressure; VC, vital capacity; IC, inspiratory capacity; FEV_1, forced expiratory volume in 1 s.

Table 3: Values of respiratory muscle strength − MIP and MEP.

Variable	Preoperative	Postoperative (2 months)	*p* value
MIP, cmH_2O	81.75 ± 22.04	74.56 ± 18.86	0.146
%MIP, cmH_2O	88% ± 25.47%	79.6% ± 19.64%	
MEP, cmH_2O	98.55 ± 22.24	88.86 ± 18.14	0.019
%MEP, cmH_2O	105.1% ± 27.96%	101.46 ± 24.16	

MIP, maximal inspiratory pressure.
MEP, maximal expiratory pressure.

The spirometric estimations were consistent with the anticipated values (VC, 92.29%; FEV_1, 88.15%; IC, 92.05%); however, at the 2-month follow-up, the VC, FEV_1, and IC decreased significantly at 3.4%, 6.83%, and 9.96%, respectively, compared with the preoperative values (Table 2). The oxygen saturation was 97 ± 1% preoperatively and 98 ± 1% at the 2-month follow-up ($p = 0.07$).

At the 2-month follow-up, the MIP was positively correlated with the VC (r = 0.41, $p = 0.004$), IC (r = 0.22, $p = 0.0026$), and FEV_1 (r = 0.59, $p = 0.0078$). Conversely, the MEP was not correlated with the VC, FEV_1, and IC.

Discussion

Based on the obtained results, there was no significant change in the respiratory muscle strength 2 months after cardiac surgery as compared with that before surgery. In this study, we described the effect of cardiac surgery on respiratory muscle strength after discharge. In previous studies, there was an 11% and a 36% decrease in the MIP 5 and 6 days after surgery, respectively.[12,13] This decrease in respiratory muscle strength may be attributed to the incisional pain in the sternum, which may hinder the performance of various tests. Whether surgeries themselves affect respiratory muscle strength or whether it is altered by the patients' inspiration in the presence of pain and abilities to perform tests postoperatively remains unclear. Thoracic wall distortion owing to median sternotomy reduces the patients' ability to breath and thoracic wall compliance. Changes in respiratory patterns, alterations in thoracic wall configuration, and decreases in thoracic wall compliance might be the mechanisms underlying the reduction of lung function measured 2 months after surgery.[30,31]

Two months after cardiac surgery, the measured lung function variables (IC, VC, and FEV_1) were correlated with the MIP. The relationship established in the acute phase between the FVC and MIP[30] remained 2 months after surgery. It has been reported that there is an association between the FVC and MIP in healthy individuals,[31] which supports the premise that lung function and respiratory muscle strength are correlated with each other. Considering these findings, it would be valuable to determine the effects of deep breathing performed during IMT that would actually alter the lung volumes positively or whether respiratory muscle strength improvement itself affects the lung volumes. The decrease in the lung function 2 months after surgery was comparatively less and consistent with the predicted values for the FEV_1, IC, and VC. This decrease may not influence patients' ability to perform daily activities; nonetheless, this could be impactful in patients with noticeably impaired lung function owing to prior cardiothoracic surgery, lung disease, or other disabilities. Notably, the lung function values at follow-up resumed to the values before surgery. The preoperative respiratory muscle strength was in congruence with the expected values. Before surgery, the mean MIP was 81.75 cmH_2O, and the mean MEP was 98.55 cmH_2O. Both higher and lower preoperative values for the MIP (66 and 84 cmH_2O) have been reported.[8,11,12] The outcomes may be dependent on the equipment for measurement, methods of tests, and expected values used for respiratory muscle strength.

In the ATS/ERS 'Statement on Respiratory Muscle Testing',[20] an MIP of >80 cmH_2O is not considered to indicate a clinically significant respiratory muscle weakness. Nambiar and Ravindra[25] reported that an MIP of >50 cmH_2O is sufficient for normal breathing and that an MEP of >60 cmH_2O is necessary for generating an efficient cough. Furthermore, an MIP below 60 cmH_2O may still be normal given that it is above the level required to sustain a normal VC.[25] Consequently, there is stagnant ambiguity regarding which degree of respiratory muscle strength is adequate for addressing postoperative lung impairment.

The effect of preoperative reduction of respiratory muscle strength in subjects after cardiac surgery has not been completely studied. Rodrigues et al.[8] established a relationship of impaired preoperative MEP and MIP (<70% of the expected value defined by Neder et al.[32]) with the requirement for extended invasive mechanical ventilation.

In cardiac surgery patients, an MIP or MEP above 75% of the predictive value has been revealed to be protective against the development of postoperative pulmonary complications, e.g. fever (temperature of >37.5 °C), atelectasis, pneumonia, and bronchitis throughout hospitalisation.[33−35] Contrarily, Riedi et al.[13] found no relationship between a weak preoperative respiratory muscle and postoperative pulmonary impairments. Thus, additional studies are required to determine the possible role of respiratory muscle strength in the progression of pulmonary impairments.

The SD for the MIP (74.56 ± 18.86 cmH_2O) and MEP (88.86 ± 18.14 cmH_2O) showed an extensive difference in respiratory muscle strength, and this difference is in agreement with earlier reports in cardiac surgery patients[10,11,16] and healthy subjects.[20] The limitation of this study was that the number of patients included was small (n = 42) and that extremely ill subjects were not included; hence, the results cannot be generalised to all cardiac surgery patients.

Further, only a few female patients were included in this study. Patients with unstable angina before surgery were excluded in accordance with the ATS/ERS statement.[27] There was no noteworthy impairment in respiratory muscle strength in this study 2 months after cardiac surgery.

The respiratory muscle strength was not impaired, which may be an essential effect in some subjects; subsequently, the relationship between lung function and inspiratory muscle strength was established. Additional studies are required to determine subjects at a risk for reduced lung function, which may cause pulmonary complications or affect physical activity capacity 2 months after cardiac surgery.

Conclusion

The respiratory muscle strength measured on the basis of the MIP and MEP was consistent with the proposed values and between the preoperative period and 2-month follow-up. The VC, IC, and FEV_1 significantly decreased 2 months after cardiac surgery. Further, there was a relationship found between reduced inspiratory muscle strength and lung function. However, the mechanism underlying the reduction of lung function after 2 months remains unknown.

Source of funding

There was no source of funding from any institution.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical approval

There is no ethical or financial issue, conflicts of interests, or animal experiments related to this research.

Authors' contributions

NAB Conceived and designed the study, is responsible for the practical part, provided research materials and helped to write the scientific publication and participated in collecting the scientific material. AMS coordinated the plan of the project and analyzed results verification and with data. Helped to write the mechanism of the muscles breathing example expected make voice. ARHA-and TMJ Helped to write the mechanism of the muscles breathing, analyzed and interpreted data, provided the samples for the research, and helped to write the scientific publication. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

References

1. Wynne Rochelle, Botti Mari. Postoperative pulmonary dysfunction in adults after cardiac surgery with Cardiopulmonary bypass: clinical Significance and implications for practice. **Am J Crit Care 2004**; 13: 384−393.
2. Ng Calvin SH, Wan Song, Yim Anthony PC, Arifi Ahmed A. Pulmonary dysfunction after cardiac surgery. **Chest 2002**; 121: 1269−1277.
3. Jensen L, Yang L. Risk factors for postoperative pulmonary complications in coronary artery bypass graft surgery patients. **Eur J Cardiovasc Nurs 2007**; 6(3): 241−246.

4. Michelle V, Conde, Adams. *Overview of the management of postoperative pulmonary complications*. Up-to-date; 2014. MA, https://www.uptodate.com/contents/overview-of-the-management-of-postoperative-pulmonary-complications.
5. Baumgarten MC, Garcia GK, Frantzeski MH, Giacomazzi CM, Lagni VB, Dias AS, et al. Pain and pulmonary function in patients submitted to heart surgery via sternotomy. **Rev Bras Cir Cardiovasc 2009**; 24(4): 497—505.
6. Zubrzycki Marek, Liebold Andreas, Skrabal Christian, Reinelt Helmut, Ziegler Mechthild, Perdas Ewelina, Zubrzycka Maria. Assessment and path physiology of pain in cardiac surgery. **J Pain Res 2018**; 11: 1599—1611.
7. Sasseron AB, Figueiredo LC, Trova K, Cardoso AL, Lima NM, Olmos SC, et al. Does the pain disturb the respiratory function after open heart surgery? **Rev Bras Cir Cardiovasc 2009**; 24(4): 490—496.
8. Rodrigues AJ, Mendes V, Ferreira PE, Xavier MA, Augusto VS, Bassetto S, et al. Preoperative respiratory muscle dysfunction is a predictor of prolonged invasive mechanical ventilation in cardio respiratory Complications after heart valve surgery. **Eur J Cardiothorac Surg 2011**; 39(5): 662—666.
9. Saglam Melda, Arikan Hulya, Savci Sema, Inal-Ince Deniz, Bosnak-Guclu Meral, Degirmence Betul, Turan Hatice Nur, Metin Demircin. Relationship between respiratory muscle strength, functional capacity and quality of life in pre-operative cardiac surgery patients. **Eur Respir Rev 2008**; 17: 39—40.
10. Barros GF, Santos Cda S, Granado FB, Costa PT, Limaco RP, Gardenghi G. Respiratory muscle training in patients submitted to coronary arterial bypass graft. **Rev Bras Cir Cardiovasc 2010**; 25(4): 483—490.
11. Savci S, Degirmenci B, Saglam M, Arikan H, Inal-Ince D, Turan HN, et al. Short-term effects of inspiratory muscle training in coronary artery bypass graft surgery: a randomized controlled trial. **Scand Cardiovasc J 2011**; 45(5): 286—293.
12. Morsch KT, Leguisamo CP, Camargo MD, Coronel CC, Mattos W, Ortiz LD, et al. Ventilatory profile of patients undergoing CABG surgery. **Rev Bras Cir Cardiovasc 2009**; 24(2): 180—187.
13. Riedi C, Mora CT, Driessen T, Coutinho Mde C, Mayer DM, Moro FL, et al. Relation between respiratory muscle strength with respiratory complication on the heart surgery. **Rev Bras Cir Cardiovasc 2010**; 25(4): 500—505.
14. Cordeiro André Luiz Lisboa, Araújo de Melo Thiago, Neves1 Daniela, Luna Julianne, Souza Esquivel Mateus, Guimarães André Raimundo França, Lago Borges Daniel, Petto Jefferson. Inspiratory muscle training and functional capacity in patients undergoing cardiac surgery. **Braz J Cardiovasc Surg 2016**; 31(2): 140—144.
15. Tung Heng-Hsin, Shen Shu-Fen, Shih Chun-Che, Chiu Kuan-Ming, Lee Jyun-Yi, Liu Chieh-Yu. Effects of a preoperative individualized exercise program on selected recovery variables for cardiac surgery patients: a pilot study. **J Saudi Heart Assoc 2012**; 24: 153—161.
16. Ferreira GM, Haeffner MP, Barreto SS, Dall'Ago P. Incentive spirometrywith expiratory positive airway pressure brings benefits after myocardial revascularization. **Arq Bras Cardiol 2010**; 94(2): 230—235.
17. Rouhi-Boroujeni Hamid, Rouhi-Boroujeni Hojjat, Rouhi-Boroujeni Parnia, Sedehi Morteza. Long-term pulmonary functional status following coronary artery bypass grafting surgery. **ARYA Atheroscler 2015 Mar**; 11(2): 163—166.
18. Taggart David P. Respiratory dysfunction after cardiac surgery: effects of avoiding cardiopulmonary bypass and the use of bilateral internal mammary arteries. **Eur J Cardiothorac Surg 2000**; 18(1): 31—37.
19. Westerdahl E, Urell C, Jonsson M, Bryngelsson IL, Hedenstrom H, Emtner M. Deep breathing exercises performed 2 months following cardiac surgery: arandomized controlled trial. **J Cardiopulm Rehabil Prev 2014**; 34(1): 34—42.
20. ATS/ERS Statement on respiratory muscle testing. **Am J Respir Crit Care Med 2002**; 166(4): 518—624.
21. Humphrey R, Malone D. Effectiveness of preoperative physical therapy for elective cardiac surgery. **Phys Ther 2015 Feb**; 95(2): 160—166.
22. Johansson Henrik, Sjöholm Rebecca, Anders Stafberg, Westerdahl Elisabeth. Breathing exercises with positive expiratory pressure after abdominal surgery—the current physical therapy practice in Sweden. **J Anesth Clin Res 2013**; 4(Issue 6): 1—4.
23. Dimitriadis Z, Kapreli E, Konstantinidou I, Oldham J, Strimpakos N. Test/retestreliability of maximum mouth pressure measurements with the MicroRPMin healthy volunteers. **Respir Care 2011**; 56(6): 776—782.
24. Nicolas Terzi, Corne Frédéric, Mouadil Amèle, Lofaso Frédéric, Normand Hervé. Mouth and nasal inspiratory pressure: learning effect and reproducibility in healthy adults. **Respiration 2010**; 80: 379—386.
25. Nambiar Veena Kiran, Ravindra Savita. Maximal respiratory pressures &their correlatesinnormal Indian adult population: a cross-sectional study. **Int J Physiother Res 2015**; 3(4): 1188—1196.
26. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. **Eur Respir J 2005**; 26(2): 319—338.
27. Wanger J, Clausen JL, Coates A, Pedersen OF, Brusasco V, Burgos F, et al. Standardisation of the measurement of lung volumes. **Eur Respir J 2005**; 26(3): 511—522.
28. Hedenstrom H, Malmberg P, Agarwal K. Reference values for lung function tests in females. Regression equations with smoking variables. **Bull Eur Physiopathol Respir 1985**; 21(6): 551—557.
29. Hedenstrom H, Malmberg P, Fridriksson HV. Reference values for lung function tests in men: regression equations with smoking variables. **Ups J Med Sci 1986**; 91(3): 299—310.
30. Urell Charlotte, Emtner Margareta, Hedenstrom Hans, Westerdahl Elisabeth. Respiratory muscle strength is not decreased in patients undergoing cardiac surgery. **J Cardiothorac Surg 2016**; 11(41): 1—5.
31. Sachs MC, Enright PL, Hinckley Stukovsky KD, Jiang R, Barr RG. Performance of maximum inspiratory pressure tests and maximum inspiratory pressure reference equations for 4 race/ethnic groups. **Respir Care 2009**; 54(10): 1321—1328.
32. Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lungfunction tests. II. Maximal respiratory pressures and voluntary ventilation. **Braz J Med Biol Res 1999**; 32(6): 719—727.
33. Bellinetti LM, Thomson JC. Respiratory muscle evaluation in electivethoracotomies and laparotomies of the upper abdomen. **J Bras Pneumol 2006**; 32(2): 99—105.
34. Hulzebos EH, Van Meeteren NL, De Bie RA, Dagnelie PC, Helders PJ. Prediction of postoperative pulmonary complications on the basis of preoperative risk factors in patients who had undergone coronary artery bypass graft surgery. **Phys Ther 2003**; 83(1): 8—16.
35. Jensen Janne Hastrup, Steffensen Birgit Fynbo, Brendstrup Tatjana, Petersen Annemette Krintel. Identification of preoperative risk factors for postoperative pulmonary complications after thoracic and abdominal surgery. **Gen surg: Open Access 2018**; 1(1): 13—18.

How to cite this article: Naseer BA, Al-Shenqiti AM, Ali ARH, Aljeraisi T. Effect of cardiac surgery on respiratory muscle strength. J Taibah Univ Med Sc 2019;14(4):337—342.